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Description

X-RAY TUBE ENERGY-ABSORBING APPARATUS

BACKGROUND OF INVENTION

[0001] The present invention relates generally to x-ray tube components and systems. More particularly, the present invention relates to an apparatus for absorbing kinetic energy within an x-ray tube before absorption by an x-ray tube housing.

[0002] An x-ray system typically includes an x-ray tube that is used in the imaging process for the generation of x-rays. The x-ray tube generates x-rays across a vacuum gap between a cathode and a rotating anode. In order to generate the x-rays, a large voltage potential is created across the vacuum gap, which allows electrons to be emitted, in the form of an electron beam. The electron beam is emitted from the cathode to a target on the anode. The target is often in the form of a cap that is brazed onto the anode and is formed of a graphite material.

[0003] In releasing of the electrons, a filament contained within the cathode is heated to incandescence by passing an electric current therein. The electrons are accelerated by the high voltage potential and impinge on the target, where they are abruptly slowed down to emit x-rays. The high voltage potential produces a large amount of heat within the x-ray tube, especially within the anode.

[0004] The cathode and the anode reside within a vacuum vessel, which is sometimes referred to as an insert or frame. The frame is typically enclosed in a housing filled with circulating, cooling fluid, such as a dielectric oil. The cooling fluid often serves two purposes: cooling the vacuum vessel, and providing high voltage insulation between the anode and the cathode.

[0005] Over time, through use of the x-ray system and as a result of material or manufacturing imperfections in the target, material fragments of the target can break away or separate from the anode. The material fragments can be released radially from the target cap and subsequently collide with the frame.

[0006] Kinetic energy of the target fragments and the abrupt collision of the fragments with the frame can cause generation of energy waves in the cooling fluid. The cooling fluid

absorbs some of the kinetic energy. The remaining kinetic energy is transmitted to the housing, where a substantial portion of the remaining energy is absorbed. The strength of the remaining kinetic energy can be sufficient to crack the housing, allowing oil to leak therethrough. Leakage of the oil can result in the malfunctioning of the x-ray tube. Also, the oil may come in contact with and negatively effect performance of other sensitive x-ray system equipment. The oil may even be undesirably released on a patient being examined.

[0007] Thus, there exists a need for an apparatus that minimizes the transfer of kinetic energy, generated from the separation of material fragments of an x-ray tube rotating target, to an x-ray tube housing that is capable of withstanding the environment within an x-ray tube.

SUMMARY OF INVENTION

[0008] The present invention provides a kinetic energy-absorbing device for an imaging tube. The energy-absorbing device includes an energy-absorbing body, which is fluidically coupled to a housing of the imaging tube. The kinetic energy can be generated from the separation of material fragments from a rotating target within the housing.

[0009] The embodiments of the present invention provide several

advantages. The invention can prevent cracking in the x-ray tube housing and thus prevent coolant leakages and the disadvantages associated therewith. The energy-absorbing device absorbs the kinetic energy, which is generated within the x-ray tube, before it can be absorbed by the housing.

[0010] Also the energy-absorbing device positioned within the x-ray tube housing can aid in the control of pressure exertions experienced within an x-ray tube. Thus, the invention can protect the structural integrity of the housing and, as a result, increase the life of the x-ray tube.

[0011] The present invention itself, together with attendant advantages, will be best understood by reference to the following detailed description, taken in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF DRAWINGS

[0012] For a more complete understanding of this invention reference should now be had to the embodiments illustrated in greater detail in the accompanying figures and described below by way of examples of the invention wherein:

[0013] Figure 1 is a schematic block diagrammatic view of a multi-slice CT imaging system utilizing an imaging tube

energy-absorbing assembly in accordance with an embodiment of the present invention.

[0014] Figure 2 is a block diagrammatic view of the multi-slice CT imaging system of Figure 1 having the imaging tube energy-absorbing assembly in accordance with an embodiment of the present invention.

[0015] Figure 3 is a cross-sectional view of an x-ray tube assembly incorporating use of the imaging tube energy-absorbing assembly in accordance with an embodiment of the present invention; and.

[0016] Figure 4 is a close-up sectional view of a rotating anode and the imaging tube energy-absorbing assembly in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0017] While the present invention is described with respect to an apparatus for minimizing the transfer of kinetic energy to an x-ray tube housing, the following apparatus is capable of being adapted for various purposes and is not limited to the following applications: computed tomography (CT) systems, radiotherapy systems, x-ray imaging systems, and other applications known in the art. The present invention may be applied to x-ray tubes, CT tubes, and other imaging tubes known in the art.

[0018] In the following description, various operating parameters and components are described for one constructed embodiment. These specific parameters and components are included as examples and are not meant to be limiting.

[0019] Also, although the present invention is primarily described with respect to absorbing kinetic energy generated from the separation of material fragments from a rotating target of an x-ray tube, the present invention may be used to absorb kinetic energy generated from other x-ray tube components and the material fragments separated therefrom.

[0020] Referring now to Figures 1 and 2, perspective and block diagrammatic views of a multi-slice CT imaging system 10 utilizing an imaging tube energy-absorbing assembly 11 in accordance with an embodiment of the present invention is shown. The imaging system 10 includes a gantry 12 that has an x-ray tube assembly 14 and a detector array 16. The x-ray tube assembly 14 has an x-ray generating device or x-ray tube 18. The tube 18 projects a beam of x-rays 20 towards the detector array 16. The tube 18 and the detector array 16 rotate about an operably translatable table 22. The table 22 is translated along a z-axis between the assembly 14 and the detector array 16 to

perform a helical scan. The beam 20 after passing through a medical patient 24, within a patient bore 26, is detected at the detector array 16. The detector array 16 upon receiving the beam 20 generates projection data that is used to create a CT image.

[0021] The tube 18 and the detector array 16 rotate about a center axis 28. The beam 20 is received by multiple detector elements 30. Each detector element 30 generates an electrical signal corresponding to the intensity of the impinging x-ray beam 20. As the beam 20 passes through the patient 24 the beam 20 is attenuated. Rotation of the gantry 12 and the operation of tube 18 are governed by a control mechanism 32. Control mechanism 32 includes an x-ray controller 34 that provides power and timing signals to the tube 18 and a gantry motor controller 36 that controls the rotational speed and position of the gantry 12. A data acquisition system (DAS) 38 samples analog data, generated from the detector elements 30, and converts the analog data into digital signals for subsequent processing thereof. An image reconstructor 40 receives the sampled and digitized x-ray data from the DAS 38 and performs high-speed image reconstruction to generate the CT image. A main controller or computer 42 stores

the CT image in a mass storage device 44.

[0022] The computer 42 also receives commands and scanning parameters from an operator via an operator console 46. A display 48 allows the operator to observe the reconstructed image and other data from the computer 42. The operator supplied commands and parameters are used by the computer 42 in operation of the DAS 38, the x-ray controller 34, and the gantry motor controller 36. In addition, the computer 42 operates a table motor controller 50, which translates the table 22 to position patient 24 in the gantry 12.

[0023] The x-ray controller 34, the gantry motor controller 36, the image reconstructor 40, the computer 42, and the table motor controller 50 may be microprocessor-based such as a computer having a central processing unit, memory (RAM and/or ROM), and associated input and output buses. The x-ray controller 34, the gantry motor controller 36, the image reconstructor 40, the computer 42, and the table motor controller 50 may be a portion of a central control unit or may each be stand-alone components as shown.

[0024] Referring now to Figure 3, a cross-sectional view of the x-ray tube assembly 14 incorporating use of the imaging

tube energy-absorbing assembly 11 in accordance with an embodiment of the present invention is shown. The imaging tube 18 includes an exterior housing 60 that has an insert or frame 62. The frame 62 may be formed from metal and contains a rotating anode 64 and a cathode 66. The frame 62 is surrounded by a coolant 68, which is circulated around the frame 62 and cooled via a pump and a heat exchanger (both of which are not shown). The coolant 68 may be in the form of an insulating dielectric oil. Electrons pass from the cathode 66 to the rotating anode 64 across a vacuum gap 70 where they impinge on the anode 64 and produce x-rays. The x-rays then pass through a window 72 in the housing 60 for scanning purposes.

[0025] The rotating anode 64 has a target 74 thereon. The target 74 may be in the form of a target cap and formed of a graphite material. As material fragments of the target 74 separate from the rotating anode 64 and collide with the frame 62, kinetic energy generated therefrom is transferred into the frame 62 and the surrounding coolant 68. The kinetic energy is transferred in the form of energy waves. The kinetic energy is partially absorbed by the coolant 68. A substantial amount of the remaining kinetic

energy is absorbed by the energy-absorbing assembly 11, such that little to zero kinetic energy is transferred into the housing 60.

[0026] The energy-absorbing assembly 11 also stabilizes and reduces pressure exertions on the housing 60, which can occur from temperature fluctuations of the components and materials contained within the x-ray tube 18. For example, as the x-ray tube 18 is operated, temperatures within the x-ray tube 18 increase and can cause expansion of the internal components and materials, such as the coolant 68. The expansion of the components and materials can exert pressure on the housing 60. Since the energy-absorbing device 11 is compressible, it aids in the stabilization of the increase in pressure by, in effect, increasing the volume within the housing 60. The increase in volume decreases the pressure on the inner walls or surfaces, such as inner surface 76, of the housing 60.

[0027] The energy-absorbing assembly 11 is directly coupled to and within the housing 60 and is fluidically coupled to the rotating target 74, via the frame 62 and the coolant 68. The energy-absorbing assembly 11 is coupled to the inner surface 76 of the housing 60. The energy-absorbing assembly 11 includes an energy-absorbing device 78 and a

pair of energy absorbing device couplers 80.

[0028] The energy-absorbing device 78 includes an energy-absorbing body 82. The energy-absorbing device 78 is oriented to receive the energy waves generated from the separation of the material fragments. In one embodiment of the present invention, the energy-absorbing device 78 is oriented to at least receive energy waves emitted within an emission range. The emission range is best seen in Figure 4 and is represented by angle α. The energy-absorbing device 78 may receive energy waves outside the emission range α. The emission range α covers a span of approximately ±30° from a perpendicular axis 84, which extends perpendicular from a center axis of rotation 86 of the rotating anode 64. The emission range α has a vertex 88 that is approximately in the center of the target 74.

[0029] Referring again to Figure 3, the energy-absorbing device 78 may be in the form of a toroidally shaped body, as shown. The energy-absorbing device 78 may also have an opening 90 for the transmission of x-rays therethrough, also as shown. Although a single energy-absorbing device is shown, any number of energy-absorbing devices may be utilized. The energy-absorbing device 78 may be of any shape or style, and may be in various locations within

the imaging tube 18.

[0030] The energy-absorbing device 78 may be formed of a foam, a closed cell foam, a polyolefin foam, a olefin foam, a polymer, a polyolefin plastic, some other material having similar properties, or a combination thereof. In an embodiment of the present invention, the energy-absorbing device 78 is formed of a closed cell polyolefin foam having an outer skin.

[0031] Although the energy-absorbing device 78 is shown as being coupled to the inner surface 76 via the pair of energy-absorbing device couplers 80, the energy-absorbing device 78 may be coupled to the housing 60 using various techniques known in the art. The techniques may include bonding, adhering, fastening, brazing, welding, spot welding, some other technique known in the art, or a combination thereof. The couplers 80 may be in the form of brackets, as shown, or may be in some other form. The couplers 80 may be in the form of fasteners or may be in the form of a cover that resides over the energy-absorbing device 78. The couplers 80 may be separate from or integrally formed as part of the housing 60.

[0032] The present invention provides an apparatus for the absorption of kinetic energy within an x-ray tube. The appa-

ratus is capable of withstanding the environment within the x-ray tube. The apparatus absorbs energy generated from the separation of material fragments from a rotating anode. The present invention also stabilizes and minimizes pressure exertions on the housing of an x-ray tube. The present invention is inexpensive to manufacture and easy to implement within an x-ray tube.

[0033] The above-described apparatus and method, to one skilled in the art, is capable of being adapted for various applications and systems known in the art. The above-described invention can also be varied without deviating from the true scope of the invention.